ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct685

A Survey on AI-Based Household Robots Focusing on Voice Assistance, Smart Kitchen Support, Home Monitoring and Autonomous Navigation

C. V. Nalawade[1]; Avinash Landage[2]; Anjali Barge[3]; Sakshi Kamble[4]

[1]Professor
[1;2;3;4]Department of Electronics and Telecommunication Engineering SPVP's S.B. Patil College of Engineering Indapur, Pune, Maharashtra, India

Publication Date: 2026/10/23

Abstract: Artificial intelligence, embedded computing and mobile robotics are steadily converging to help with everyday domestic work. This survey reviews the main research threads that, taken together, cover the building blocks of a low-cost AI household robot: (i) home-service and care robots [1], [2], [10]; (ii) voice assistants and social interaction with home assistants [3], [4], [13], [15]; (iii) LLM-based smart-home agents and home managers [18], [20]; (iv) AI-assisted kitchen support [12]; and (v) navigation, localization, semantic mapping and robot safety [6]–[9], [14], [16], [17]. We compare their focus, strengths and limitations, identify gaps (notably the scarcity of affordable platforms that combine conversation, cooking support, mobility, obstacle awareness and monitoring), and use the findings to motivate the design of a low-cost household robot. The proposed system places a Raspberry Pi at the centre, connected to a microphone, speaker, display, camera, ultrasonic sensors, a motor driver and a wheeled base. A conversational AI layer interprets natural-language requests, while obstacle detection, emergency stop and motor time-outs are kept in local safety logic outside the AI loop. Design considerations, a proposed function-to-module mapping, safety logic and an evaluation plan are presented.

Keywords: *Household Robot; Conversational AI; Raspberry Pi; Voice Control; Smart Kitchen; Home Monitoring; Obstacle Avoidance; Autonomous Navigation; Survey.*

How to Cite: C. V. Nalawade; Avinash Landage; Anjali Barge; Sakshi Kamble (2026) A Survey on AI-Based Household Robots Focusing on Voice Assistance, Smart Kitchen Support, Home Monitoring and Autonomous Navigation.
International Journal of Innovative Science and Research Technology, 11(10), 1391-1395.
https://doi.org/10.38124/ijisrt/26oct685

I. INTRODUCTION

Homes are full of repetitive chores that can gain from intelligent help. Cooking calls for close attention to recipes and timers, daily routines depend on reminders and shopping lists, and household surveillance usually relies on fixed cameras or a smartphone. Common voice assistants are handy but stay in one place, whereas mobile robots can sense and move around yet often lack natural spoken interaction. Voice is attractive because it is hands-free, which suits the kitchen where the user's hands are often busy [13].

Beyond the user interface, a household robot is a mechatronic and software system: its behaviour is shaped by conversational AI [18], [20], kitchen support [12], navigation and sensing [6], [9], monitoring, and the safety logic that decides when the robot may move [8]. The literature usually treats these aspects separately. Our project, a low-cost AI household robot built around a Raspberry Pi, sits at their intersection.

➢ *Scope and Method*

This survey analyses the reference works [1]–[20] and relates them to the proposed hardware and software modules. The quantitative statements below are those reported by the respective authors. The survey does not claim experimental results for our own system, and the goal of saving up to one hour of daily kitchen work is an objective of the project, not an experimentally proven result.

II. BACKGROUND

➢ *Household and Service Robots*

Care-O-bot was an early mobile home-care platform able to fetch and carry items and perform other supporting duties at home [1]. Yamazaki et al. described a home-assistant robot meant to improve domestic activity and

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct685

sustain continuous task execution, covering recognition, manipulation and recovery from failures [2]. Work on the Toyota HSR shows that mobile manipulation widens what a service robot can physically do, although it also raises mechanical and software complexity [10].

Mobility sets robots apart from stationary assistants, but a practical home robot must weigh capability against cost and reliability.

➢ *Voice Assistance and Conversational AI*

Raspberry Pi-based smart-home work links speech recognition with sensors and appliances [13]. Luria et al. studied Vyo, a centralised home assistant, and highlighted qualities such as being engaging, unobtrusive, respectful and reassuring [3]. Sato et al. demonstrated context-aware interaction through pointing gestures and environment data [4], and AURA merges voice and gesture control using a Raspberry Pi, camera, microphone and speaker [15]. LLM-driven agents go beyond classic command-and-response: in SAGE, a language model chooses the actions used to talk to users and operate devices [18], and a Smart Home Manager joins IoT platforms, conversational AI and GPT-4 to deliver proactive household services [20]. Network availability, latency, privacy and erroneous actions remain key engineering concerns.

➢ *Smart Kitchen and Recipe Assistance*

Shukla et al. put forward an IoT and AI cooking system in which computer vision enables smart cooking support while the person stays in charge [12]. The robot can therefore read out or show instructions, run timers and answer questions without handling hot cookware, which lowers mechanical complexity and risk while keeping the practical benefit.

➢ *Navigation, Localization and Mapping*

Indoor service robots must cope with people, moving obstacles, interaction and energy use. The survey in [6] sorts navigation methods into reactive, predictive, model-based and learning-based families. SARL* improves human-aware navigation through a dynamic local goal and a map-derived safe action space [9]. Vision-based localization has been explored using ceiling-space density [7], SLAM studies concentrate on localization and mapping [16], and semantic mapping and object search show that home robots profit from knowing what rooms and objects mean [16], [17]. For a low-cost prototype, simple obstacle-aware motion is realistic, with SLAM and semantic navigation left as later extensions.

➢ *Safety and Human-Robot Interaction*

Haddadin et al. reviewed how collisions can be detected, isolated and identified for robots that share space with people [8]. Human-centred navigation studies point out that social acceptability matters as much as path length and travel time [14], and social HRI research stresses human expectations, behaviour and social intelligence [11]. Household adoption also depends on perceived usefulness [19].

➢ *Motivation*

Household robots have important applications in kitchen assistance, daily reminders, entertainment, home monitoring and support for busy households. However, effective operation requires the integration of voice interaction, conversational AI, actuation, sensing, monitoring and safety mechanisms.

Existing studies address different parts of this problem. Some focus on voice assistants and smart-home agents, while others concentrate on service-robot manipulation, navigation or kitchen vision. However, these aspects are often studied separately, and there is limited work combining conversation, recipe support, mobility, obstacle sensing and camera monitoring on a low-cost embedded platform.

Therefore, this survey is motivated by the need to systematically study and compare existing approaches, identify their strengths and limitations, and determine the research gap for developing a low-cost AI household robot. The findings provide a foundation for selecting suitable interaction, sensing, actuation and safety approaches for the proposed system.

➢ *Comparative Analysis*

Table 1 summarises the main reviewed works along the dimensions most relevant to a household robot, and Table 2 compares common household-assistance approaches with the proposed platform.

Table 1 Side-by-Side Comparison of the Reviewed Works.

Work	Main focus	Strength	Limitation
[1] Care-O-bot	Mobile home-care platform	Fetch-and-carry support	Early, complex platform
[2] Home assistant	Aging-society assistant	Recognition, manipulation, failure recovery	Mechanical and software complexity
[10] Toyota HSR	Mobile manipulation	Wider physical capability	Cost and complexity
[3] Vyo	Centralised home assistant	Social, unobtrusive qualities	Mostly design study
[15] AURA	Voice and gesture control on Raspberry Pi	Low-cost multimodal HRI	Limited task scope
[18] SAGE	LLM smart-home agent	Flexible interaction	Needs reliable device interfaces
[20] Home Manager	IoT + GPT-4 services	Proactive services	Latency, privacy, network

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct685

[12] Smart cooking	IoT and vision cooking support	Human stays in control	No mobility
[6], [9] Navigation	Human-aware navigation	Safe action space in crowds	May exceed Raspberry Pi budget
[8] Collisions	Detect, isolate, identify	Safety foundation	Not a full home system

Table 2 Functional Comparison of Household-Assistance Approaches and the Proposed Platform.

Capability	Voice assistant	Recipe app	Home camera	Mobile robot	Proposed
Voice control	Yes	Limited	No	Sometimes	Yes
Mobility	No	No	No	Yes	Yes
Recipe guidance	Limited	Yes	No	Limited	Yes
Music	Yes	Limited	No	Limited	Yes
Timers / reminders	Yes	Limited	No	Limited	Yes
Shopping list	Limited	Limited	No	Limited	Yes
Camera monitoring	No	No	Yes	Limited	Yes
Obstacle detection	No	No	No	Yes	Yes
Conversational AI	Yes	Limited	No	Limited	Yes

III. PROPOSED AI HOUSEHOLD ROBOT SYSTEM

➢ *Architecture*

The Raspberry Pi acts as the central processing and communication node. The microphone captures speech, which is passed to the conversational AI layer, and answers return through the speaker and display. Recipe, reminder, music and shopping features run as software modules. Movement goes through the motor driver and DC motors, while ultrasonic readings feed a local safety decision. The camera streams monitoring data over Wi-Fi to an authorised phone or device. Four data paths are used: (i) user voice, microphone, Raspberry Pi, AI/ChatGPT, then speaker or display; (ii) command, Raspberry Pi, motor driver, motors; (iii) ultrasonic sensor, control logic, obstacle decision; and (iv) camera, Raspberry Pi, Wi-Fi, user's phone.

A central design rule is that cloud or conversational AI must stay outside the direct safety loop. Even if the network drops, the robot has to halt when it senses an obstacle. High-level AI services never directly govern low-level motor safety.

➢ *Hardware Components Required*

Table 3 lists the components and their roles in the system.

Table 3 Component Summary. Detailed Specifications to be Verified Against Official Datasheets.

Component	Role in system
Raspberry Pi	Central node: runs voice, AI, recipe, reminder, music, shopping, navigation and safety modules; communicates over Wi-Fi
Microphone	Captures user speech for the voice module
Speaker / display	Delivers spoken answers, recipe steps and on-screen information
Camera	Provides monitoring video to an authorised phone or device over Wi-Fi
Ultrasonic sensors	Measure obstacle distance; feed the local stop/avoid decision
Motor driver and DC motors	Execute movement commands on the wheeled base
Battery and power rails	Motor power regulated separately from sensitive electronics

➢ *Function-to-Module Mapping (Proposed)*

Table 4 Proposed Mapping Between User Functions and System Modules.

Function	Intended behaviour	Safety / notes
Open request	Forwarded to the AI layer; answered by speaker and/or display	Network latency and wrong answers possible
Recipe	Step-by-step guidance and timers	No handling of hot cookware
Music / reminders / shopping	Plays music, manages timers, reminders and grocery list	Software-only modules
Move	Motor commands while the ultrasonic sensor keeps scanning	Stops or alters course on obstacle; motor time-out
Monitor	Camera switched on for remote viewing	Authorisation required
Stop	Immediate halt of motors	Highest priority; local, independent of AI

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct685

➢ *Working Procedure*

On start-up the Raspberry Pi initialises the camera, sensors, display and motor controller, followed by the network link and the AI interface. The user speaks, and the request is captured and interpreted. Where deeper reasoning is needed, the request is forwarded to the AI layer, and the answer is delivered by speaker and/or display. For a movement request, the Pi sends motor commands while the ultrasonic sensor keeps scanning; on detecting an obstacle, the robot stops or alters its course.

➢ *Safety, Privacy and Reliability*

Since the robot works close to people, safety is treated as a property of the whole system. The following measures are proposed: (i) ultrasonic readings are checked both before and during motion; (ii) a physical emergency-stop switch is provided; (iii) every motor command carries a time-out so that a lost connection ends in a safe stop; (iv) motor power is regulated separately from sensitive electronics; (v) obstacle detection, emergency stopping, motor time-outs and power protection are handled locally on the robot; and (vi) camera access requires authorisation because household video can reveal private details. Battery life, ultrasonic limitations, navigation limits, AI network latency and camera privacy are recognised constraints of the prototype.

IV. FUTURE SCOPE

- Marathi, Hindi and English interaction, and richer multi-turn AI dialogue.
- Appliance control, online grocery ordering and health reminders.
- Better navigation using wheel encoders and an IMU, followed by SLAM and semantic object search [16], [17].
- Face recognition with privacy safeguards.
- Manipulation capability, added step by step after safety validation [10].

➢ *Proposed Evaluation Plan*

To make the project results comparable with the reviewed literature, we propose the following metrics: speech-recognition and command-interpretation accuracy in quiet and noisy rooms; end-to-end response latency from utterance to spoken answer (mean ± SD over repeated trials); obstacle stop distance and stop time; motor time-out and emergency-stop response; battery run time during movement and monitoring; camera streaming reliability over Wi-Fi; and user trials to assess usefulness and acceptance [19], including whether the stated goal of saving up to one hour of daily kitchen work is realistic. Results should be reported separately for online and degraded-network conditions, since the AI layer depends on network availability.

V. RESEARCH GAP AND CONCLUSION

Existing studies show solid progress on individual abilities but pay less attention to combining them in an inexpensive, student-scale platform. Voice assistants mostly remain fixed in place; recipe tools tend to rely on a phone or screen; stationary cameras cover limited space; and advanced service robots can be costly and mechanically intricate. LLM-based agents add flexible interaction but need dependable integration [18], [20], and state-of-the-art navigation may exceed the computing budget of a basic Raspberry Pi prototype [6], [16].

The reviewed works cover complementary parts of the problem: [1], [2], [10] show the value and cost of mobile service robots; [3], [13], [15] show voice and social interaction; [18], [20] show LLM-driven home services; [12] shows kitchen support without manipulation; and [6]–[9], [14] show navigation and safety needs. No reviewed system combines conversation, kitchen support, mobility, obstacle sensing and monitoring on low-cost embedded hardware. The proposed Raspberry Pi-based system, with local safety logic and a defined evaluation plan, targets exactly this gap, and forms a practical base to which SLAM, semantic navigation and manipulation can be added step by step.

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ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26oct685

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